# Refine Search

**Search Results -**

| Terms | Documents |
|---|---|
| L12 and (fuel with cell).clm. | 8 |

**Database:**
US Pre-Grant Publication Full-Text Database
US Patents Full-Text Database
US OCR Full-Text Database
EPO Abstracts Database
JPO Abstracts Database
Derwent World Patents Index
IBM Technical Disclosure Bulletins

**Search:** L13

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Recall Text Clear Interrupt

## Search History

**DATE: Monday, June 27, 2005** Printable Copy Create Case

| Set Name side by side | Query | Hit Count | Set Name result set |
|---|---|---|---|
| *DB=USPT; THES=ASSIGNEE; PLUR=YES; OP=OR* | | | |
| L13 | L12 and (fuel with cell).clm. | 8 | L13 |
| L12 | electrode$ and @ad<=20021129 and (gas$ with pressur$ with (greater or larger or smaller$)) and hybrid$ | 167 | L12 |
| L11 | l2 and @ad<=20021129 and (gas$ with pressur$ with (greater or larger or smaller$)) and hybrid$ | 1 | L11 |
| L10 | l2 and (fuel$ with cell)and @ad<=20021129 and (gas$ with pressur$ with (greater or larger or smaller$)) and hybrid$ | 1 | L10 |
| L9 | L8 and pressure$ | 1 | L9 |
| L8 | 6521369.pn. | 1 | L8 |
| L7 | l2 and (fuel$ with cell)and @ad<=20021129 and (gas$ with pressur$ with electrode with smaller$) and hybrid$ | 1 | L7 |
| L6 | l2 and (fuel$ with cell)and @ad<=20021129 and (gas$ with pressur$ with electrode with lower$) and hybrid$ | 0 | L6 |

| | | | |
|---|---|---|---|
| L5 | l2 and (fuel$ with cell)and @ad<=20021129 and (gas$ with pressur$ with electrode with greater) and hybrid$ | 0 | L5 |
| *DB=PGPB,USPT; THES=ASSIGNEE; PLUR=YES; OP=OR* | | | |
| L4 | l2 and (fuel$ with cell).clm. and @ad<=20021129 and (gas$ with pressur$ with electrode with greater) and hybrid$ | 0 | L4 |
| *DB=USPT; THES=ASSIGNEE; PLUR=YES; OP=OR* | | | |
| L3 | (fuel$ with cell).clm. and @ad<=20021129 and (gas$ with pressur$ with electrode).clm. and hybrid$ | 3 | L3 |
| *DB=PGPB,USPT; THES=ASSIGNEE; PLUR=YES; OP=OR* | | | |
| L2 | (fuel$ with cell).clm. and @ad<=20021129 and (gas$ with pressur$ with electrode) | 490 | L2 |
| *DB=USPT; THES=ASSIGNEE; PLUR=YES; OP=OR* | | | |
| L1 | (fuel$ with cell) and @ad<=20021129 and (gas$ with pressur$ with electrode) | 773 | L1 |

END OF SEARCH HISTORY

# Hit List

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**Search Results** - Record(s) 1 through 8 of 8 returned.

☐ 1. Document ID: US 6808832 B2

L13: Entry 1 of 8 File: USPT Oct 26, 2004

US-PAT-NO: 6808832
DOCUMENT-IDENTIFIER: US 6808832 B2

TITLE: Fuel cell humidifying system

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

☐ 2. Document ID: US 6686084 B2

L13: Entry 2 of 8 File: USPT Feb 3, 2004

US-PAT-NO: 6686084
DOCUMENT-IDENTIFIER: US 6686084 B2

TITLE: Gas block mechanism for water removal in fuel cells

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

☐ 3. Document ID: US 6627340 B1

L13: Entry 3 of 8 File: USPT Sep 30, 2003

US-PAT-NO: 6627340
DOCUMENT-IDENTIFIER: US 6627340 B1

TITLE: Fuel cell hydrogen supply systems using secondary fuel to release stored hydrogen

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

☐ 4. Document ID: US 6555262 B1

L13: Entry 4 of 8 File: USPT Apr 29, 2003

US-PAT-NO: 6555262
DOCUMENT-IDENTIFIER: US 6555262 B1

TITLE: Wicking strands for a polymer electrolyte membrane

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

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☐ 5. Document ID: US 6521369 B1

L13: Entry 5 of 8 File: USPT Feb 18, 2003

US-PAT-NO: 6521369
DOCUMENT-IDENTIFIER: US 6521369 B1

TITLE: Flooding-reducing fuel cell electrode

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

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☐ 6. Document ID: US 6348278 B1

L13: Entry 6 of 8 File: USPT Feb 19, 2002

US-PAT-NO: 6348278
DOCUMENT-IDENTIFIER: US 6348278 B1

TITLE: Method and system for supplying hydrogen for use in fuel cells

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

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☐ 7. Document ID: US 6193929 B1

L13: Entry 7 of 8 File: USPT Feb 27, 2001

US-PAT-NO: 6193929
DOCUMENT-IDENTIFIER: US 6193929 B1

TITLE: High storage capacity alloys enabling a hydrogen-based ecosystem

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

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☐ 8. Document ID: US 6054229 A

L13: Entry 8 of 8 File: USPT Apr 25, 2000

US-PAT-NO: 6054229
DOCUMENT-IDENTIFIER: US 6054229 A
**** See image for Certificate of Correction ****

TITLE: System for electric generation, heating, cooling, and ventilation

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

| Terms | Documents |
|---|---|
| L12 and (fuel with cell).clm. | 8 |

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L13: Entry 2 of 8 File: USPT Feb 3, 2004

DOCUMENT-IDENTIFIER: US 6686084 B2
TITLE: Gas block mechanism for water removal in fuel cells

Application Filing Date (1):
20020104

Assignee Name (1):
Hybrid Power Generation Systems, LLC

Assignee Group (1):
Hybrid Power Generation Systems, LLC Torrance CA 02

Brief Summary Text (4):
When the quantity of liquid water formed on the cathode side exceeds the liquid water carried away by the oxidizing gas, there is a condition called a "flooded state" or "flooding." In a flooded state, the liquid water remains on the surface of the cathode electrode and obstructs the dispersion of the oxidizing gas onto the surface of the cathode. This in turn results in a drop in the cell's voltage and amperage output. Ultimately, flooding will stop the cell's operation.

Brief Summary Text (7):
It is known in the art to remove water at the cathode side by utilizing an electrode layer comprised of a porous base area with water repellency and plurality of penetration areas higher in water permeability scattered over or formed through the base area. This facilitates the oozing of water generated on the catalytic layer of the PEM fuel cell into the gas channels through the areas of higher permeability. These types of apparatus have the disadvantage of focusing on removing water at the catalytic area adjacent to the polyelectrolyte membrane; being limited in the quantity of water that can be removed and being limited in mass transfer of reactant gas to the polyelectrolyte membrane.

Brief Summary Text (9):
It is also known in the art to remove fluid at electrodes by positioning a porous support layer near and in fluid communication with each electrode to facilitate fluid transport to and away from each electrode. The porous support layer includes hydrophobic pores and hydrophilic pores integrated throughout the layer. The fuel and oxidizing gasses are supplied through the hydrophobic pores and water is removed through the hydrophilic pores. This apparatus has the disadvantages of focusing on removing water at the electrode area; being limited in quantity of water that can be removed and being limited in mass transfer of cathode gas to the polyelectrolyte membrane.

Brief Summary Text (18):
A multiplicity of porous gas block mediums positioned in the cathode plate adjacent to each feed side interdigitated channel at points where liquid water forms during the operation of the fuel cell and having pores sized such that liquid water in the feed side interdigitated channels is sipped off by capillary flow and cathode gas is blocked. A gas diffusion layer closely positioned over the first surface of the cathode plate and flow field therein. A water channel at the second major surface of the cathode plate, or a water manifold at the perimeter of the cathode plate, in

fluid communication with each porous gas block medium through which pressurized water flows and where the pressure of the water and gas in feed side interdigitated channels is greater than the pressure of coolant in the water channel such that liquid water flows from each porous gas block medium into the cooling channel or a manifold whereby the water may be the coolant.

Brief Summary Text (20):
A multiplicity of porous gas block mediums positioned adjacent to the dead-ends of each of the feed side interdigitated channels having a bubble point in the range of between about 10 psig to about 70 psig such that liquid water is sipped out of the feed side interdigitated channels by capillary flow and cathode gas is blocked. A gas diffusion layer closely positioned over the first surface of the cathode plate and flow field therein. A water channel at the second major surface of the cathode plate, or a manifold at the cathode plate perimeter, in fluid communication with each porous gas block medium through which pressurized coolant flows and where the pressure of the cathode gas in feed side interdigitated channels is greater than the pressure of water in water channels (but does not exceed the bubble point pressure) such that liquid water flows from the porous gas block medium to the water channel or manifold.

CLAIMS:

1. A plate assembly for use in a fuel cell comprised of: one of a cathode plate with cathode gas and an anode plate with anode gas having a first major surface and a second oppositely opposed major surface; a flow field for a gas within the first major surface comprised of feed side interdigitated channels and exhaust side interdigitated channels such that in the operation of the fuel cell there is flow of said gas by convection from feed side interdigitated channels to exhaust side interdigitated channels; at least one porous gas block medium positioned in the one of a cathode and anode plate adjacent to the flow field having pores sized such that liquid water in the flow field is sipped off by capillary flow and said gas is blocked; a gas diffusion layer positioned over the first surface of the one of a cathode and anode plate and flow field therein; and a liquid water channel at the second major surface of the one of a cathode and anode plate and in fluid communication with the at least one porous gas block medium such that liquid water flows from the porous gas block medium to the water channel.

3. The plate assembly of claim 1 wherein the at least one porous gas block medium is positioned adjacent where liquid water accumulates in the flow field as the fuel cell operates.

5. A plate assembly for use in a fuel cell with a pressurized gas and a pressurized water comprised of: one of a cathode plate with cathode gas and an anode plate with anode gas having a first major surface and a second oppositely opposed major surface; a flow field for said pressurized gas within the first major surface having: a feed side having a feed side internal plenum in fluid communication with one or more feed side interdigitated channels having width and with dead-ends; and an exhaust side having an exhaust side internal plenum in fluid communication with a plurality of exhaust side interdigitated channels having width and with dead-ends, wherein the feed side and exhaust side interdigitated channels are in an intedigitated configuration defining land between the interdigitated channels such that in the operation of the fuel cell there is flow of said gas by convection from feed side interdigitated channels to exhaust side interdigitated channels; a multiplicity of porous gas block mediums positioned in the one of a cathode and anode plate adjacent to each feed side interdigitated channel at points where liquid water forms or collects during the operation of the fuel cell and having pores sized such that liquid water in the feed side interdigitated channels is sipped off by capillary flow and said gas is blocked; a gas diffusion layer positioned over the first surface of the one of a cathode and anode plate and flow field therein; and a water channel at the second major surface of the one of a

cathode and anode plate in fluid communication with each porous gas block medium through which pressurized coolant flows and where the pressure of said gas in feed side interdigitated channels is greater than the pressure of coolant in the cooling channel and the pressure difference is less than the bubble point pressure of the gas block such that liquid water flows from each porous gas block medium into the cooling channel.

10. A cathode plate assembly for use in a fuel cell with a pressurized cathode gas and a pressurized water comprised of: a cathode plate that is a four sided polygon having a first major surface, a second oppositely opposed major surface, and a first and third and second and fourth oppositely opposed pairs of edges where the first edge is at a higher gravitational potential energy than the third edge; a flow field for pressurized cathode gas within the first major surface and having: a feed side internal plenum running parallel to the first edge of the cathode plate; a plurality of feed side interdigitated channels having widths that are in fluid communication with and substantially perpendicular to the feed side internal plenum that extend toward the third edge and terminate at dead-ends; an exhaust side internal plenum running parallel to the third edge of the cathode plate; a plurality of exhaust side interdigitated channels having widths that are in fluid communication with and substantially perpendicular to the exhaust side internal plenum that extend toward the first edge and terminate at dead-ends and which are interdigitated between the feed side interdigitated channels so as to define land between the interdigitated channels; wherein the ratio of pressure drop of the cathode gas flow over the land between a feed side interdigitated channel and a neighboring exhaust side interdigitated channel and the feed side interdiditated channel cathode gas flow is in the range of about 8:1 to 15:1 such that cathode gas flows by convection from the feed side interdigitated channel to a neighboring exhaust side interdigitated channel; a multiplicity of porous gas block mediums positioned adjacent to the dead-ends of each of the feed side interdigitated channels having a bubble point in the range of between about 10 psig to about 70 psig such that liquid water is sipped out of the feed side interdigitated channels by capillary flow and cathode gas is blocked; a gas diffusion layer positioned over the first surface of the cathode plate and flow field therein, and a water channel at the second major surface of the cathode plate in fluid communication with each porous gas block medium through which pressurized water flows and where the pressure of the cathode gas in feed side interdigitated channels is greater than the pressure of water in water channels and the pressure difference is less than the bubble point pressure such that liquid water flows from the porous gas block medium to the water channel.

12. A method for removing liquid water at one of a cathode side and an anode side of an electrochemical fuel cell comprised of the steps of: providing one of a cathode plate and an anode plate having a first major surface and a second oppositely opposed major surface; providing a flow field for gas within the first major surface comprised of feed side interdigitated channels and exhaust side interdigitated channels such that in the operation of the fuel cell there is flow of said gas by convection from feed side interdigitated channels to exhaust side interdigitated channels; providing at least one porous gas block medium positioned in the one of a cathode and anode plate adjacent to the flow field having pores sized such that liquid water in the flow field is sipped off by capillary flow and said gas is blocked; providing a gas diffusion layer positioned over the first surface of the one of a cathode and anode plate and flow field therein; and providing a liquid water channel at the second major surface of the one of a cathode and anode plate and in fluid communication with the at least one porous gas block medium passing said gas through the fuel cell so as to generate an electric current, whereby water is sipped off through a porous medium to the liquid water channel.

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L13: Entry 1 of 8 File: USPT Oct 26, 2004

DOCUMENT-IDENTIFIER: US 6808832 B2
TITLE: Fuel cell humidifying system

Application Filing Date (1):
20010130

Brief Summary Text (6):
A unit cell is comprised by a core of a solid polymer membrane of ionic conductivity in intimate contact with a fuel-electrode (anode) and an air-electrode (cathode) on each surfaces thereof. When hydrogen gas is supplied through the fuel gas passage formed as an U-shaped groove on the surface facing the fuel-electrode and air is supplied simultaneously through the oxidizer passage formed as an U-shaped groove on the surface facing the air-electrode, electricity is generated as a result of electrochemical reaction between the electrodes in each unit cell.

Brief Summary Text (9):
For this reason, a conventional approach is to devise a humidifying system to humidify dry gases such as the air to be supplied to the air-electrode side and the hydrogen to be supplied to the fuel-electrode side by passing both gases through a water permeable humidifier so as to obtain wet gases for humidifying the solid polymer membrane.

Brief Summary Text (11):
This type of humidifier is provided with a hollow threaded membrane to permit water to infiltrate in the direction of the film thickness (refer to Japanese Patent Application, First Publication, No. Hei 7-71795, and Japanese Patent Application, First Publication, No. Hei 8-273687), and for example, humidification of the air-electrode side is carried out as follows.

Brief Summary Text (12):
That is, while dry air is being forced through a jacket containing a packing comprised by an assembly of hollow thread membranes using a charging apparatus such as a supercharger, wet out-gas discharged from the air-electrode side is forced through the hollow section inside the hollow thread membrane so that the moisture contained in the wet out-gas can infiltrate through the porous surface of the hollow thread membrane and disperse on the outside of the hollow thread membrane as water vapor to add humidity to the dry air flowing through the inter-thread spaces formed by the thread membranes.

Brief Summary Text (16):
Also, it is also possible that, if dust particles and the like having diameters larger than the inside diameters of the hollow section or the pores of the membrane are mixed in the wet out-gas from the fuel cell, such particles may block the entrance to the hollow section or plug up the pores of the membrane to cause a pressure increase at the entrance to the hollow thread membrane or decrease in the recoverable amount (percent) of water, resulting in degradation in the performance of the inherent capability of the fuel cell humidifying system.

Detailed Description Text (7):
The air-electrode (cathode) of the fuel cell 1 is connected to the air piping 7 for

supplying outside air (referred to as dry air Ad) which is inhaled from an intake opening 11 and serving as the oxidizer, to an oxidizer inlet opening 12; and the out-air piping 8 for discharging the out-gas (referred to as wet out-air OAw hereinbelow) which flows from the oxidizer outlet opening 13, to an exhaust opening 14.

Detailed Description Text (25):
The air-electrode of the fuel cell 1 is connected to an air piping 7 for supplying outside air (dry air Ad) which is inhaled from an intake opening 11 and serving as the oxidizer, to an oxidizer inlet opening 12; and an out-air piping 8 for discharging the out-gas (wet out-air OAw) which is discharged from the oxidizer outlet opening 13, to the exhaust opening 14.

Detailed Description Text (35):
The reverse flow cleansing mode of operation is carried out not only while the fuel cell 1 is stopped but also while the vehicle is moving. For example, when the fuel cell 1 is installed in an electric vehicle or a hybrid vehicle, this mode of operation is carried out while the vehicle is stopped or moving, if the pressure detected by the pressure sensor 35 at the inlet of the hollow thread membrane exceeds a preset value for each output pressure setting by 5 kPa.

CLAIMS:

1. A fuel cell humidifying system for supplying a fuel cell with a wet gas produced by providing a dry gas and an exhaust gas discharged from the fuel cell into a humidifier which has a water permeable membrane and for recovering moisture contained in the exhaust gas in the dry gas to produce the wet gas, comprising: a flow path switching mechanism for switching gas passages leading to the humidifier, wherein the flow path switching mechanism enables the dry gas to flow through an exhaust gas passage in the humidifier.

2. A fuel cell humidifying system for supplying a fuel cell with a wet gas produced by providing a dry gas and an exhaust gas discharged from the fuel cell into a humidifier which has a water permeable membrane and for recovering moisture contained in the exhaust gas in the dry gas to produce the wet gas, comprising: a flow path switching mechanism for switching gas passages leading to the humidifier, wherein the flow path switching mechanism enable to reverse a direction of flow of exhaust gas in the humidifier by switching the gas passage.

3. A fuel cell humidifying system for supplying a fuel cell with a wet gas produced by providing a dry gas and an exhaust gas discharged from the fuel cell into a humidifier which has a water permeable membrane and for recovering moisture contained in the exhaust gas in the dry gas to produce the wet gas, comprising: a flow path switching mechanism for switching gas passages leading to the humidifier, wherein the flow path switching mechanism enables the dry gas to flow to an exhaust gas passage in the humidifier when the outside air temperature is equal to 0.degree. C. or lower.

4. A fuel cell humidifying system for supplying a fuel cell with a wet gas produced by providing a dry gas and an exhaust gas discharged from the fuel cell into a humidifier which has a water permeable membrane and for recovering moisture contained in the exhaust gas in the dry gas to produce the wet gas, comprising: a flow path switching mechanism for switching gas passages leading to the humidifier, wherein the flow path switching mechanism enables the dry gas to flow to an exhaust gas passage in the humidifier when pressure at an inlet of the water permeable membrane exceeds a preset value.

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L13: Entry 4 of 8 File: USPT Apr 29, 2003

Y

DOCUMENT-IDENTIFIER: US 6555262 B1
TITLE: Wicking strands for a polymer electrolyte membrane

Abstract Text (1):
In a hydrogen gas fuel cell a polymer electrolyte membrane, or "PEM," is located between two layers composed of a catalyst material such that a sandwich-like assembly is formed. An anode electrode and a cathode electrode, each composed of a thin sheet of porous material that is permeable to liquid and gas, are situated on either side of the sandwich-like assembly such that one surface of each electrode abuts a catalyst layer. The remaining surface of each electrode abuts a conductive nonporous bipolar plate having grooves cut therein. Wicking strands composed of a trilobed fiber are located in between each catalyst layer and the adjacent PEM, and arranged in a repetitive pattern such that the strands do not cross over each other. Each wicking strand abutting the PEM surface facing the anode electrode has one end situated in a reservoir of liquid water. Each wicking strand abutting the PEM surface facing the cathode electrode drains into an exhaust reservoir.

Application Filing Date (1):
20000208

Assignee Name (1):
Hybrid Power Generation Systems, LLC

Assignee Group (1):
Hybrid Power Generation Systems, LLC Los Angeles CA 02

Brief Summary Text (2):
This invention relates to fuel cells and, more particularly, to fuel cells incorporating a solid polymer electrolyte membrane to conduct protons between the electrodes of the fuel cell and including wicking strands to hydrate the membrane.

Brief Summary Text (6):
The simplest fuel cell consists of two electrodes separated by an electrolyte. The electrodes are electrically connected through an external circuit, with a resistive load lying in between them. Solid polymer electrochemical fuel cells generally employ a membrane electrode assembly, or "MEA," consisting of a solid polymer electrolyte membrane, or "PEM," also known as a proton exchange membrane, disposed between the two electrodes. The electrodes are formed from porous, electrically conductive sheet material, typically carbon fiber paper or cloth, that allows gas diffusion. The PEM readily permits the movement of protons between the electrodes, but is relatively impermeable to gas. It is also a poor electronic conductor, and thereby prevents internal shorting of the cell.

Brief Summary Text (7):
A fuel gas is supplied to one electrode, the anode, where it is oxidized to produce protons and free electrons. The production of free electrons creates an electrical potential, or voltage, at the anode. The protons migrate through the PEM to the other electrode, the positively charged cathode. A reducing agent is supplied to the cathode, where it reacts with the protons that have passed through the PEM and the free electrons that have flowed through the external circuit to form a reactant

product. The MEA includes a catalyst, typically platinum-based, at each interface between the PEM and the respective electrodes to induce the desired electrochemical reaction.

Brief Summary Text (16):
One solution has been to increase the temperature differential by increasing the humidification temperature. However, the increased humidification temperature causes an increase in the partial pressure of the water vapor which is greater than the attendant increase in the partial pressure of the fuel gas. This unequal increase in partial pressures causes a decrease in the quantity of fuel gas per unit of volume in the humidified gas mixture entering the fuel cell which, in turn, adversely affects the performance of the fuel cell.

Brief Summary Text (35):
Briefly, in a fuel cell a PEM is located between two layers composed of a catalyst material such that a sandwich-like assembly is formed. The fuel cell further includes two electrodes, each comprised of a thin sheet of porous material that is permeable to liquid and gas. The two electrodes are situated on either side of the sandwich-like assembly such that one surface of each electrode abuts a catalyst layer.

Brief Summary Text (36):
The remaining surface of each electrode respectively abuts a nonporous bipolar plate. The bipolar plate has grooves for gas flow, and serves as a manifold to distribute fuel gas across the abutting electrode. The two bipolar plates are conductive, and are electrically connected by an external circuit.

Brief Summary Text (38):
Hydrogen fuel gas flows through the grooves in the anode bipolar plate, diffuses through the anode electrode, and reacts with the catalyst to produce free electrons and H.sup.+ ions. The electrons flow to the cathode electrode by means of the external circuit, and the H.sup.+ ions migrate through the PEM to the cathode electrode. The wicking strands abutting the PEM surface facing the anode electrode communicate liquid water from a reservoir to the foregoing PEM surface to maintain adequate hydration of the PEM.

Brief Summary Text (39):
Oxygen gas flows through the grooves of the cathode bipolar plate and reacts with the H.sup.+ ions and free electrons to form liquid water. The wicking strands abutting the PEM surface facing the cathode electrode communicate liquid water from the surface of the PEM to an exhaust reservoir.

Detailed Description Text (2):
An exploded view of fuel cell 11 is shown in FIG. 1. Fuel cell 11 is comprised of anode side 13 and cathode side 15, and further includes PEM 17 formed from a solid ion exchange polymer, such as polyperflouorosulfonic acid, e.g., a Naflon.RTM. membrane produced by E. I. DuPont de Nemours. PEM 17 separates the two sides electronically, yet provides for the conduction of protons between them, the significance of which will be subsequently explained. Anode side 13 is comprised of wicking strands 19, anode catalyst layer 21, anode electrode 23, and anode bipolar plate 25. Cathode side 15 is comprised of wicking strands 27, cathode catalyst layer 29, cathode electrode 31, and cathode bipolar plate 33.

Detailed Description Text (3):
Catalyst layers 21 and 29 are situated against the two approximately planar faces of PEM 17, respectively, to form a sandwich-like assembly. Catalyst layers 21 and 29 are porous and composed of any one of a number of platinum-based compounds well known to those skilled in the art which precipitate the dissociation of hydrogen gas to form H.sup.+ ions and free electrons. Electrodes 23 and 31 are each composed of a thin sheet of porous material that is permeable to liquid and gas. Carbon

fiber paper or cloth is commonly used for this purpose.

Detailed Description Text (12):
Bipolar plates 25 and 33 are formed from conductive nonporous material that is imperious to gas and liquid. Electrical circuit 41 electrically connects bipolar plates 25 and 33. Anode bipolar plate 25 includes face 42, parallel grooves 43, inlet 44 and exhaust 45. Grooves 43 are cut into otherwise planar face 42. Grooves 43 fluidly communicate with each other, with inlet 44, and with exhaust 45. Anode bipolar plate 25 abuts anode electrode 23 such that anode electrode 23 is exposed to grooves 43 and any gas flowing therethrough.

Detailed Description Text (13):
Cathode bipolar plate 33 includes face 46, parallel grooves 47, inlet 48 and exhaust 49. Grooves 47 are cut into otherwise planar face 46. Grooves 47 fluidly communicate with each other, with inlet 48, and with exhaust 49. Cathode bipolar plate 33 abuts cathode electrode 31 such that cathode electrode 31 is exposed to grooves 47 and any gas flowing therethrough.

Detailed Description Text (14):
FIG. 3 is a schematic cross sectional view of fuel cell 11. FIG. 4 is a fragmentary, enlarged cross sectional view of fuel cell 11. As particularly shown in FIG. 3, strands 19 communicate with water 51 in water reservoir 53, inlet 44 fluidly communicates with hydrogen fuel gas 55 from a hydrogen gas source (not shown), and exhaust 45 fluidly communicates exhaust gas 57 with an exhaust reservoir (not shown). The pressure of the hydrogen gas source is maintained at a pressure sufficiently greater than that of the exhaust reservoir to ensure fluid flow from the hydrogen gas source, through grooves 43 (not shown in FIG. 3), and into the exhaust reservoir. The pressure in water reservoir 53 is maintained at a level slightly greater than the pressure in grooves 43 to prevent or reduce the leakage of hydrogen fuel gas 55 into water reservoir 53.

Detailed Description Text (15):
With respect to cathode side 15 of fuel cell 11, strands 27 communicate with water reservoir 59, inlet 48 fluidly communicates with oxygen gas 61 from a oxygen gas source (not shown), and exhaust 49 fluidly communicates exhaust gas 63 with an exhaust reservoir (not shown). The pressure of the oxygen gas source is maintained at a pressure greater than the pressure in the exhaust reservoir to ensure the fluid flow of oxygen gas 61 through grooves 47.

Detailed Description Text (16):
Upon flowing into grooves 43, hydrogen fuel gas 55 flows through anode electrode 23 and comes into contact with catalyst layer 21, whereupon it dissociates to form H.sup.+ ions and free electrons in accordance with the following equation:

Detailed Description Text (19):
The H.sup.+ protons traverse PEM 17 to cathode electrode 31 where, precipitated by catalyst layer 29, they are reduced by oxygen gas 61 and the free electrons conducted by circuit 41 from anode bipolar plate 25, to form water. The foregoing reaction is expressed by the chemical equation:

Detailed Description Text (21):
The other face of anode bipolar plate 25 may abut the cathode of an adjacent fuel cell. In such a configuration, this face would have the grooves, oxygen gas inlet, and exhaust heretofore described in conjunction with cathode bipolar plate 33, and it would function in an identical manner. Such a plate is called a bipolar plate because it abuts the anode electrode of one fuel cell and the cathode electrode of an adjacent fuel cell. The adjacent fuel cells are electrically connected in series. This is known as a "stacked" fuel cell configuration.

Detailed Description Text (24):

Furthermore, the wicking strands of the present invention do not need to be bonded to the anode or cathode, respectively, or to the PEM, and thus no analysis of the composition of the foregoing fuel cell components is necessary because the wicking strands need not be composed of a material capable of bonding to the foregoing components. The wicking strands of the present invention may be used with fuel cell electrodes and PEMs composed of virtually any material.

CLAIMS:

1. An apparatus for hydrating a polymer electrolyte membrane in a fuel cell, comprising: a wicking strand for conducting water by capillary action between said polymer electrolyte membrane and a location apart from said polymer electrolyte membrane, wherein said wicking strand abuts said polymer electrolyte membrane; said strand having symmetrical lobes; and partially enclosed channels being formed between adjacent symmetrical lobes, whereby water is conducted by said strand by having it flow through said partially enclosed channels.

6. The hydration apparatus as defined in claim 5 wherein: the fuel cell includes a catalyst layer; and said strands are located in between the catalyst layer and the membrane.

11. The hydration apparatus as defined in claim 6 wherein the fuel cell uses a fuel comprised of hydrogen gas.

12. The hydration apparatus as defined in claim 4 wherein: the fuel cell includes an anode catalyst layer; the membrane includes an anode-side surface; said strand lies in between and abuts the anode catalyst layer and the anode-side surface; the location including a reservoir for containing a volume of water; and said strand communicates with the reservoir, whereby water flows from the reservoir, through said strand, and onto the anode-side surface.

14. The hydration apparatus as defined in claim 13 wherein: the fuel cell includes an anode electrode; and the anode electrode abuts the anode catalyst layer.

15. The hydration apparatus as defined in claim 14 wherein: the fuel cell includes an anode bipolar plate and a fuel source; and the anode bipolar plate includes anode manifold means for fluidly communicating the fuel source with the anode electrode.

16. The hydration apparatus as defined in claim 4 wherein: the fuel cell includes a cathode catalyst layer; the membrane includes a cathode-side surface; and said strand lies in between and abuts the cathode catalyst layer and the cathode-side surface, whereby water is removed from the cathode-side surface of the membrane to the location.

18. The hydration apparatus as defined in claim 17 wherein: the fuel cell includes a cathode electrode; and the cathode electrode abuts the cathode catalyst layer.

19. The hydration apparatus as defined in claim 18 wherein: the fuel cell includes a cathode bipolar plate and a reduction gas source; and the cathode bipolar plate includes cathode manifold means for fluidly communicating the reduction gas source with the cathode electrode.

20. An apparatus for hydrating a membrane in a fuel cell comprising: a membrane having two major sides, an anode-facing side and a cathode-facing side; an anode catalyst layer lying adjacent said anode-facing side; a wicking strand for conducting water, with said wicking strand abutting said anode-facing side of said membrane and abutting said anode catalyst layer; and an anode electrode abutting said anode catalyst layer.

24. The hydration apparatus defined in claim 23 further comprising: a cathode catalyst layer lying adjacent the cathode-facing side; said strand being located in between and abutting the cathode-facing side and the cathode catalyst layer, and a cathode electrode abutting the cathode catalyst layer, whereby water is removed from the cathode-facing side of the membrane.

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L27: Entry 1 of 1 File: USPT Feb 18, 2003

DOCUMENT-IDENTIFIER: US 6521369 B1
TITLE: Flooding-reducing fuel cell electrode

Brief Summary Text (5):
A PEM fuel cell is advantageously formed of a membrane electrode assembly sandwiched between two graphite flow field plates. Conventionally, the membrane electrode assembly consists of random-oriented carbon fiber paper electrodes (anode and cathode) with a thin layer of a catalyst material, particularly platinum or a platinum group metal coated on isotropic carbon particles, such as lamp black, bonded to either side of a proton exchange membrane disposed between the electrodes. In operation, hydrogen flows through channels in one of the flow field plates to the anode, where the catalyst promotes its separation into hydrogen atoms and thereafter into protons that pass through the membrane and electrons that flow through an external load. Air flows through the channels in the other flow field plate.to the cathode, where the oxygen in the air is separated into oxygen atoms, which joins with the protons through the proton exchange membrane and the electrons through the circuit, and combine to form water. Since the membrane is an insulator, the electrons travel through an external circuit in which the electricity is utilized, and join with protons at the cathode. The air stream on the cathode side removes the water formed by combination of the hydrogen and oxygen. Combinations of such fuel cells are used in a fuel cell stack to provide the desired voltage.

Detailed Description Text (25):
As noted above, an electrochemical fuel cell includes a membrane electrode assembly that comprises an ion exchange membrane sandwiched between two electrodes, at least one of which is the above-described graphite sheet. A typical substrate for the ion (or proton) exchange membrane is a porous material, such as a glass cloth or a polymeric material such as a porous polyolefin like polyethylene or polypropylene. Preferably, for use in a commercially practical electrochemical fuel cell, the substrate for the PEM should be between about 10 and 200 microns thick, with an average pore diameter of about 0.1 to about 1.0 microns and porosity of about 50 to 98%. Perfluorinated polymers, like polytetrafluoroethylene, are sometimes preferred. The substrate can then be impregnated to control properties such as porosity. Styrene impregnants such as trifluorostyrene and substituted trifluorostyrenes have been suggested as particularly suitable for use in fuel cell proton exchange membranes. One preferred impregnant useful in the practice of the invention is available from Ion Power Inc. under the tradename Liquione-1100; an especially preferred impregnant is a perfluorinated polymer membrane sold under the tradename Nafion.RTM. by DuPont Company.

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L25: Entry 1 of 1 File: USPT Nov 12, 2002

DOCUMENT-IDENTIFIER: US 6480767 B2
TITLE: Control system for hybrid vehicle

Detailed Description Text (7):
Referring to FIG. 2, the structure and operation of the electric power distribution controller 6 are as follows. Input from various vehicle-mounted sensors (not shown) to the electric power distribution controller 6 are physical quantity and conversion quantity corresponding to the physical quantity representing the vehicle states, such as accelerator pedal actuation amount, throttle opening, rpm speed of the engine, vehicle speed, motor drive current, motor rpm speed, generator drive current, generator rpm speed and auxiliary equipment load.

Detailed Description Text (9):
A battery state calculator 21 of the electric power distribution controller 6 obtains electric power coming in or out from the battery 5 from current coming in or out from the battery 5 and voltage between terminals at that time, estimates state of charge (SOC) of the battery 5, detects a temperature of the battery from a temperature sensor (not shown) disposed in the battery 5, and calculates energy conversion efficiency (charging efficiency) when electric energy is charged from the battery 5 and energy conversion efficiency (discharging efficiency) when the electric energy is drawn from the battery 5 based on the SOC and the temperature of the battery.

Detailed Description Text (186):
Next, using FIG. 48, the electric power distribution controller 210 will be explained in detail. Input to the electric power distribution controller 210 are physical quantity or conversion amount corresponding to physical quantity indicative of vehicle speed such as accelerator pedal actuation amount, throttle opening, rpm speed of the engine, vehicle speed, motor drive current, motor rpm speed, generator drive current, generator rpm speed, load of auxiliary equipment and temperature of the battery.

Detailed Description Text (312):
For example, a first aspect of the present invention is a control system for a hybrid vehicle for controlling the hybrid vehicle, comprising a motor for allowing the vehicle to run, an electric power generating apparatus, and a battery storing electric power generated by the electric power generating apparatus and stores regenerative electric power generated by the motor at the time of deceleration of the vehicle, the battery discharges if necessary, the control system comprises: a consumed electric power calculator for calculating current electric power consumption of the vehicle, a battery state calculator for calculating battery state, a physical quantity per effective power calculator for calculating a predetermined physical quantity concerning the electric power generating apparatus per unit amount for a sum ("effective electric power") of the electric power consumption and electric power which can be consumed when surplus electric power charged into the battery is discharged in future when electric power equal to or greater than the electric power consumption is generated based on the battery state for various electric power consumption and various electric power generation, a

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threshold value calculator for obtaining a threshold value having the same unit as that of the physical quantity per effective power using predetermined calculation to select operating modes of the electric power generating apparatus and the battery, an operating mode selecting means for selecting the operating modes of the electric power generating apparatus and the battery based on comparison between the threshold value and the physical quantity per effective power corresponding to the electric power consumption, and a target electric power generation calculator for calculating a target electric power generation amount for the electric power generating apparatus from the threshold value and the physical quantity per effective power.

Detailed Description Text (368):
A thirty-first aspect of the present invention is a control system for a hybrid vehicle comprising a motor for allowing the vehicle to run, an electric power generating apparatus for generating electric power using fuel, and a battery for storing electric power generated by the electric power generating apparatus and regenerative electric power generated by the motor at the time of deceleration of the vehicle, the control system comprising a consumed electric power calculator for calculating current electric power consumption of the vehicle, a threshold value calculator for calculating a threshold value for selecting operating modes for the electric power generating apparatus and the battery based on charging state of the battery, operating mode selecting means for selecting operating mode for the electric power generating apparatus and the battery based on effective fuel consumption rate curve at the time of direct distribution indicative of fuel consumption rate per unit effective electric power when electric power equal to electric power consumption is generated by the electric power generating apparatus, and the threshold value, and the current electric power consumption obtained by the consumed electric power calculator, and a target generated electric power calculator for calculating target generated electric power of the electric power generating apparatus based on an effective fuel consumption rate curve at the time of charging of surplus electric power indicative of fuel consumption rate per unit effective electric power when electric power greater than electric power consumption is generated by the electric power generating apparatus, effective fuel consumption rate curve at the time of the direct distribution, the threshold value, the current electric power consumption obtained by the consumed electric power calculator, and an operating mode selected by the operating mode selecting means.

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L16: Entry 1 of 1 File: USPT Oct 1, 2002

DOCUMENT-IDENTIFIER: US 6458478 B1
TITLE: Thermoelectric reformer fuel cell process and system

Brief Summary Text (3):
Fuel cells convert chemical energy contained in a fuel directly into electrical energy. Because the conversion does not involve conversion of heat into mechanical energy, fuel cell efficiencies can exceed the Carnot Cycle limit by at least a factor of two. Also because they do not involve air combustion, use of fuel cells can reduce local air pollution, reduce quantities of greenhouse gases in the atmosphere, reduce oil imports, and reduce noise. For example as discussed by Berlowitz and Darnell for a current mid-sized automobile about 18% of the energy in the fuel is converted to work to drive the wheels, whereas, a vehicle with a fuel cell, utilizes 36% of the fuel's energy to achieve the same result. All fuel cells contain an anode and a cathode that are separated by an electrolyte. A hydrogen-rich gas is fed to the anode and oxygen is fed to the cathode. A catalyst separates the proton and electron in hydrogen atoms, allowing the protons to pass through a selective membrane. The electrons flow through an external circuit and combine with the oxygen ions and hydrogen ions, to form only water and electricity. The effectiveness of the chemical-to-electrical energy conversion is heavily dependent upon the choice of the electrolyte. Consequently, the electrolyte determines the category of the fuel cell.

Detailed Description Text (4):
The output of the LTS reactor is directed to hydrogen separator 40, which might be a ceramic or metal membrane, a pressure swing adsorber, or a temperature swing adsorber. Two streams leave the hydrogen separator. One stream 44 consists almost entirely of hydrogen and is directed to condenser 34 where excess moisture in the hydrogen stream is condensed to a saturation level prior to being fed into fuel cell 50, which operates at optimum efficiency when the hydrogen entering it is saturated. The other stream 42, mostly carbon dioxide and carbon monoxide, mixes with steam prior to entering mixer 70. The sensitive heat contained in stream 42 is also used to vaporize fuel 1 entering the system at mixer 70. Fuel cell 50 can be of several types, such as a proton exchange membrane type as taught by Edlund and Pledger of Northwest Power Systems, LLC, or a phosphoric acid type which are well known. The oxidant for the fuel cell is air 2 from an external source that is directed to the cathode by a compressor. There will be four streams leaving fuel cell 50: the output electricity 100, H.sub.2 O 53, an exhaust air stream containing waste heat 55, and H.sub.2 51. Waste heat 55 is used in heat exchanger 32 to heat the portion of H.sub.2 O stream 53 that with the input fuel 1 near the stoichiometric ratio of the input fuel-water reaction prior to entering mixer 70. To ensure that the fuel cell will operate at maximum efficiency, 80% of the hydrogen entering the fuel cell should be consumed. Therefore, hydrogen stream 51 should contain approximately 20% of the hydrogen entering the fuel cell. Hydrogen stream 51 is either recycled as stream 52 to reenter the fuel cell, or is stored in hydrogen storage system 54, or both. The hydrogen storage system can be a metal hydride, a nanotube system or any other disclosed hydrogen storage technology. In the case of a metal hydride, a heat source is required for the release of the stored hydrogen. The heat source in the instant invention is from the waste heat

500 contained in exhaust air stream 55 exiting heat exchanger 32, or during startup is from an electrical storage device. The heat used for the hydrogen storage system 54 is ultimately released to the atmosphere or external heat regenerative devices 300. During the idle stage of the hydrogen storage system (no release from this system), waste heat 500 is exhausted to the atmosphere or could be used to heat a passengers cabin in a vehicle application and to heat a building or provide hot water in a stationary application. If the hydrogen storage system 54 is at maximum storage capacity then the recycled hydrogen 51 will be directly diverted as stream 52 back into the fuel cell 50.

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L21: Entry 1 of 1 File: USPT Feb 18, 2003

DOCUMENT-IDENTIFIER: US 6521369 B1
TITLE: Flooding-reducing fuel cell electrode

Abstract Text (1):
An electrode for an electrochemical fuel cell is provided. More particularly, an electrode formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second opposed surfaces of the sheet, is provided. The size, shape and/or placement of the channels, and/or the density of the sheet, is engineered so as to reduce or minimize flooding in the fuel cell.

Application Filing Date (1):
20001116

Brief Summary Text (2):
The invention relates to an engineered electrode for an electrochemical fuel cell, comprising an article formed of a flexible graphite sheet that is fluid permeable and has enhanced isotropy with respect to thermal and electrical conductivity, and which is formed so as to minimize or reduce the flooding which can at times be observed with prior flexible graphite sheets when used as an electrochemical fuel cell electrode.

Brief Summary Text (4):
An ion exchange membrane fuel cell, more specifically a proton exchange membrane (PEM) fuel cell, produces electricity through the chemical reaction of hydrogen and oxygen in the air. Within the fuel cell, electrodes denoted as anode and cathode surround a polymer electrolyte. A catalyst material stimulates hydrogen molecules to split into hydrogen atoms and then, at the membrane, the atoms each split into a proton and an electron. The electrons are utilized as electrical energy. The protons migrate through the electrolyte and combine with oxygen and electrons to form water.

Brief Summary Text (5):
A PEM fuel cell is advantageously formed of a membrane electrode assembly sandwiched between two graphite flow field plates. Conventionally, the membrane electrode assembly consists of random-oriented carbon fiber paper electrodes (anode and cathode) with a thin layer of a catalyst material, particularly platinum or a platinum group metal coated on isotropic carbon particles, such as lamp black, bonded to either side of a proton exchange membrane disposed between the electrodes. In operation, hydrogen flows through channels in one of the flow field plates to the anode, where the catalyst promotes its separation into hydrogen atoms and thereafter into protons that pass through the membrane and electrons that flow through an external load. Air flows through the channels in the other flow field plate to the cathode, where the oxygen in the air is separated into oxygen atoms, which joins with the protons through the proton exchange membrane and the electrons through the circuit, and combine to form water. Since the membrane is an insulator, the electrons travel through an external circuit in which the electricity is utilized, and join with protons at the cathode. The air stream on the cathode side

removes the water formed by combination of the hydrogen and oxygen. Combinations of such fuel cells are used in a fuel cell stack to provide the desired voltage.

Brief Summary Text (6):
One limiting factor to the use of flexible graphite sheets as the cathode for PEM fuel cells is the accumulation of water at or in the electrodes, which can interfere with operation of the fuel cell. Indeed, since the cathodic side of the fuel cell is the site of water formation during fuel cell operation, "flooding" of the cathode can occur, which physically blocks the oxygen atoms from joining with the protons, with resulting inoperability of the fuel cell.

Brief Summary Text (13):
This considerable difference in properties, i.e. anisotropy, which is directionally dependent, can be disadvantageous in some applications. For example, in gasket applications where flexible graphite sheet is used as the gasket material and in use is held tightly between metal surfaces, the diffusion of fluid, e.g. gases or liquids, occurs more readily parallel to and between the major surfaces of the flexible graphite sheet. It would, in most instances, provide for greater gasket performance, if the resistance to fluid flow parallel to the major surfaces of the graphite sheet ("a" direction) were increased, even at the expense of reduced resistance to fluid diffusion flow transverse to the major faces of the graphite sheet ("c" direction). With respect to electrical properties, the resistivity of anisotropic flexible graphite sheet is high in the direction transverse to the major surfaces ("c" direction) of the flexible graphite sheet, and substantially less in the direction parallel to the major faces of the flexible graphite sheet ("a" direction). In applications such as electrodes for fuel cells, it would be of advantage if the electrical resistance transverse to the major surfaces of the flexible graphite sheet ("c" direction) were decreased, even at the expense of an increase in electrical resistivity in the direction parallel to the major faces of the flexible graphite sheet ("a" direction).

Brief Summary Text (15):
Flexible graphite sheet can be provided with channels, which are preferably smooth-sided, and which pass between the parallel, opposed surfaces of the flexible graphite sheet and are separated by walls of compressed expanded graphite. When the flexible graphite sheet functions as an electrode in an electrochemical fuel cell, and is placed so as to abut the ion exchange membrane, so that the "tops" of the walls of the flexible graphite sheet abut the ion exchange membrane.

Brief Summary Text (16):
The potential of a flexible graphite sheet to flood when utilized as the cathode in a PEM fuel cell is addressed by the present invention.

Brief Summary Text (18):
The present invention provides an electrode for a PEM fuel cell. The electrode is formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second opposed surfaces of the sheet. The transverse fluid channels are advantageously formed by mechanically impacting an opposed surface of the graphite sheet to displace graphite within the sheet at predetermined locations to provide a channel pattern. The transverse fluid channels are separated by walls of compressed expanded graphite.

Brief Summary Text (19):
By engineering the geometry and/or location of the channels in the sheet or the characteristics of the sheet itself, water outflow from and through the sheet can be modified, and flooding, especially at the cathodic side of the fuel cell, can be reduced or even eliminated. For example, if it is determined that flooding is more likely near the outlet of the fuel cell, the channels can be designed so as to have a larger diameter than at the inlet, where gas flow to the membrane and catalyst

are the primary concern. Moreover near the outlet, the shape and/or arrangement of the channels can be engineered, such that water outflow through the electrode and gas inflow at the inlet side are each encouraged. Channel pattern density (i.e., the number of channels per square centimeter of sheet) and density of the flexible graphite sheet itself can also be advantageously employed in this regard. Likewise, combinations of the foregoing can be utilized to optimize gas inflow and water outflow.

Detailed Description Text (17):
In the practice of this invention, the flexible graphite sheet is provided with channels, which are preferably smooth-sided, and which pass between the parallel, opposed surfaces of the flexible graphite sheet and are separated by walls of compressed expanded graphite. It is the "tops" of the walls of the flexible graphite sheet that actually abut the ion exchange membrane, when the inventive flexible graphite sheet functions as an electrode in an electrochemical fuel cell.

Detailed Description Text (20):
In accordance with the present invention, the flexible graphite sheet can be designed, or engineered, such that flooding of the fuel cell, especially on the cathodic side, can be reduced or avoided. More specifically, the location along the flexible graphite sheet where flooding is most likely to occur, when the sheet is employed as a fuel cell electrode, can be identified, and the channels at or near that location can be formed having a larger cross-sectional diameter than other channels, in order to encourage water flow through those larger diameter channels. For instance, if it is determined that flooding is more likely to occur at or near the outlet of the fuel cell, then the channels at or near the outlet region can be formed so as to be larger in cross-section than the remaining channels.

Detailed Description Text (21):
Alternatively, or in addition, the shape of the channels can be engineered to help prevent flooding. As noted above, the channels can be formed such that the openings at one of the surfaces of the flexible graphite sheet are larger than the openings at the other surface. Although it may be desirable throughout the majority of the flexible graphite sheet electrode to form the channels such that the larger openings are arrayed towards the flow field plate of the fuel cell, to facilitate gas flow to the membrane, the channels can be formed so that the larger openings are arrayed towards the membrane at those locations prone to flooding (such as at or near the outlet) to facilitate water flow away from the membrane (or vice versa). Moreover, the pattern density of the channels can be designed such that the channels are more densely situated, or less densely situated but larger in cross-section, at or near the potential flooding locations, again to encourage water flow away from those areas.

Detailed Description Text (22):
Furthermore, the density of the graphite sheet itself can be advantageously employed to reduce or eliminate flooding. More specifically, forming the sheet such that its density (especially at or near those locations where flooding is most likely) is greater than about 1.3 g/cc, and more preferably greater than about 1.5 g/cc, results in an electrode less apt to flooding in an electrochemical fuel cell. Most preferred densities in this regard are between about 1.5g/cc and about 1.75 g/cc.

Detailed Description Text (23):
In an especially preferred embodiment, the channels through the flexible graphite sheet of the present invention can be engineered such that differently oriented or shaped channels are arrayed in a pattern at or near the potential flooding locations. Thus, to facilitate both gas flow away from the flow field plate and towards the membrane, and water flow away from the membrane, the channels at or near the potential flooding location(s) of the fuel cell can comprise both channels whose larger openings face the membrane and channels whose larger openings face the

flow field plate. These differently oriented channels can be simply alternated, or they can be arrayed in a pattern designed to optimize both gas flow and flooding-reduction. In this way, gas flow to the membrane can be maximized to the extent possible, even in those locations where there is a flooding danger.

Detailed Description Text (25):
As noted above, an electrochemical fuel cell includes a membrane electrode assembly that comprises an ion exchange membrane sandwiched between two electrodes, at least one of which is the above-described graphite sheet. A typical substrate for the ion (or proton) exchange membrane is a porous material, such as a glass cloth or a polymeric material such as a porous polyolefin like polyethylene or polypropylene. Preferably, for use in a commercially practical electrochemical fuel cell, the substrate for the PEM should be between about 10 and 200 microns thick, with an average pore diameter of about 0.1 to about 1.0 microns and porosity of about 50 to 98%. Perfluorinated polymers, like polytetrafluoroethylene, are sometimes preferred. The substrate can then be impregnated to control properties such as porosity. Styrene impregnants such as trifluorostyrene and substituted trifluorostyrenes have been suggested as particularly suitable for use in fuel cell proton exchange membranes. One preferred impregnant useful in the practice of the invention is available from Ion Power Inc. under the tradename Liquione-1100; an especially preferred impregnant is a perfluorinated polymer membrane sold under the tradename Nafion.RTM. by DuPont Company.

Detailed Description Text (27):
In order to facilitate and/or enable the dissociation/association reactions required for fuel cell operation, a catalyst metal is loaded on the two opposed major surfaces of the PEM. Most commonly, the catalyst is a noble metal like platinum or a platinum group metal, often loaded on graphite or carbon particles. The catalyst can be loaded directly to the surface of the PEM, or a catalyst-loaded moiety, such as activated carbon paper, can be bonded to either surface of the PEM, as would be familiar to the skilled artisan. In operation, the fluid (i.e., either hydrogen gas or oxygen gas, depending on the "side" of the membrane electrode assembly in question) contacts the catalyst. In the case of hydrogen, on the anodic side of the assembly, the catalyst catalyzes the dissociation of the hydrogen to its constituent protons and electrons; the protons then migrate through the proton exchange membrane, and the electrons are utilized as electrical energy. In the case of oxygen, on the cathodic side of the assembly, the catalyst catalyzes the association of the protons and electrons, with the oxygen, to form water.

Detailed Description Text (28):
Advantageously, the catalyst is selectively loaded on or at the proton exchange membrane in a pattern determined by the channel pattern of the electrode that faces the particular PEM side. Most preferably, the catalyst is arrayed on the PEM at locations corresponding to the walls forming channels of the graphite sheet electrode as described above, in order to maximize catalyst effectiveness. In this way, less catalyst is needed for similar electrical outputs from the fuel cell, resulting in significant savings and other advantages, such as reduced waste disposal needs.

Detailed Description Text (29):
More particularly, in operation, the reaction catalyzed by the catalyst metal, that is, the dissociation of hydrogen molecules and atoms into constituent protons and electrons, and the re-association of the protons and electrons, in combination with oxygen, into water, occurs at the point where the surfaces of the electrode meet (or abut) the ion exchange membrane. It is at this location and, effectively, only at this location, where dissociated electrons can be conducted along the electrode and dissociated protons can migrate across the membrane (and vice versa with respect to the cathodic side of the fuel cell). Thus, it is only at or near where the walls of the channels formed in the inventive graphite sheet abut the ion exchange membrane, where catalyst should be selectively loaded.

Detailed Description Text (30):
It may also be possible to reduce further the potential flooding of the flexible graphite sheet of the present invention when used as an electrode in an electrochemical fuel cell by rendering the sheet more hydrophobic (as opposed to untreated flexible graphite sheet) in order to help prevent the potential flooding resulting from water formation at or near the cathode. To do so, a water resistant additive can be used to coat or impregnate the sheet, providing added hydrophobicity while not substantially degrading the properties of the sheet useful in forming an electrochemical fuel cell cathode. Preferred water resistant additives include fluoropolymers, such as dispersions of polytetrafluoroethylene (i.e., Teflon.TM.) material.

Detailed Description Text (35):
In order to reduce the potential for flooding when flexible graphite sheet 10 is employed as an electrode in an electrochemical fuel cell, channels 20 are engineered by, for instance, engineering one or more of protrusions 75, 175, 275 and 375, such as by using larger or smaller size protrusions. Likewise, rollers 70, 72 can be engineered so as to array protrusions 75, 175, 275 and/or 375 in a specific pattern or arrangement, as discussed hereinabove. For instance, rollers 70, 72 can be engineered such that protrusions 75, 175, 275 and/or 375 of differing sizes are arrayed so that the channels at or near a potential flooding location have a larger cross-sectional diameter than other channels (as seen in FIGS. 4, 4 (A)). Alternatively, or in addition, rollers 70, 72 can be fabricated such that protrusions 75, 175, 275 and/or 375 form channels 20 so that the larger openings are arrayed towards the membrane at those locations needed to facilitate water flow away from the membrane (as seen in FIGS. 1, 1(A)). Moreover, rollers 70, 72 can be fabricated such that channels 20 are more densely situated at or near the potential flooding locations, again to encourage water flow away from those areas (as seen in FIGS. 2, 2(A)).

Detailed Description Text (36):
In an especially preferred embodiment, rollers 70, 72 are designed such that differently oriented or shaped channels 20 are arrayed in a pattern at or near the potential flooding locations. This can be accomplished by arraying protrusions 75, 175, 275 and/or 375 on each of rollers 70, 72 as illustrated in FIG. 6(A). Indeed, in this manner, sheet 110 of FIGS. 1, 1(A) can be formed, since it would be necessary to have shaped protrusions 75, 175, 275 and/or 375 impacting sheet 110 from either opposed surface 30, 40 to form channels 20 having larger opening 50 on both opposed surfaces 30, 40 on the same sheet while using only one set of rollers 70, 72. Likewise, as shown in FIGS. 3, 3(A), protrusions 75, 175, 275 and/or 375 on rollers 70, 72 can be formed so as to be complementary in shape, and aligned so as to create channels 22 having "hybrid" or a combination of the shapes which can be formed using protrusions 75, 175, 275 and/or 375 which are not complementary (as seen in FIGS. 1(A), 2(A), 4(A), 5(A)).

Detailed Description Text (37):
As noted, it is also possible to treat flexible graphite sheet 110, 112, 114, 116, 118 (and, more particularly, flexible graphite sheet 110, 112, 114, 116, 118 intended to be used as the cathode in electrochemical fuel cell 500) with a water resistant additive to further deter flooding. Moreover, flexible graphite sheet 110, 112, 114, 116, 118 can be treated with the water resistant additive either before or after resin curing, although prior to resin curing is more desirable. For instance, a resin-impregnated flexible graphite sheet 110, 112, 114, 116, 118 treated in accordance with the present invention, can be cured to at least about 250.degree. C., more advantageously at least about 350.degree. C. for at least about 30 minutes. If sheet 110, 112, 114, 116, 118 is not resin-impregnated, curing is typically at a temperature of at least about 350.degree. C. for at least about 30 minutes.

Detailed Description Text (39):
The primary criteria for the amount of water resistant additive to be applied to flexible graphite sheet 110, 112, 114, 116, 118 is the added hydrophobicity of the sheet while maintaining the desirable criteria for use of sheet 110, 112, 114, 116, 118 as a cathode in electrochemical fuel cell 500. Generally, flexible graphite sheet 110, 112, 114, 116, 118 should exhibit a weight gain in the range of about 2% to about 34% in order to achieve the desired characteristics.

Detailed Description Text (40):
The channeled gas permeable flexible graphite sheet 110, 112, 114, 116, 118 of FIGS. 1-5(A) is used as one or both electrodes in an electrochemical fuel cell 500 shown schematically in FIGS. 9, 10 and 10(A).

Detailed Description Text (41):
FIG. 9, FIG. 10 and FIG. 10(A) show, schematically, the basic elements of an electrochemical fuel cell, more complete details of which are disclosed in U.S. Pat. Nos. 4,988,583 and 5,300,370 and PCT WO 95/16287 (Jun. 15, 1995) and each of which is incorporated herein by reference.

Detailed Description Text (42):
With reference to FIG. 9, FIG. 10 and FIG. 10(A), the fuel cell indicated generally at 500, comprises electrolyte in the form of a plastic e.g. a solid polymer ion exchange membrane 550; channeled flexible graphite sheet electrodes 110, 112, 114, 116 and/or 118 in accordance with the present invention; and flow field plates 1000, 1100 which respectively abut electrodes 110, 112, 114, 116 and/or 118. Pressurized fuel is circulated through grooves 1400 of fuel flow field plate 1100 and pressurized oxidant is circulated through grooves 1200. The above described electrochemical fuel cell is combined with others in a fuel cell stack to provide the desired level of electric power as described in the above-noted U.S. Pat. No. 5,300,370.

Detailed Description Text (44):
The operation of fuel cell 500 requires that the electrodes 110, 112, 114, 116 and/or 118 be porous to the fuel and oxidant fluids, e.g. hydrogen and oxygen, to permit these components to readily pass from the grooves 1400, 1200 through electrodes 110, 112, 114, 116 and/or 118 to contact the catalyst 600 on the surfaces of the membrane 550, as shown in FIG. 10(A), and enable protons derived from hydrogen to migrate through ion exchange membrane 550. In the electrode 110, 112, 114, 116 and/or 118 of the present invention, channels 20 are positioned to adjacently cover grooves 1400, 1200 of the flow field plates so that the pressurized gas from the grooves passes through the smaller openings 60 of channels 20 and exits the larger openings 50 of channels 20 perhaps other than in an engineered portion of electrode 110, 112, 114, 116 and/or 118, in accordance with the present invention). The initial velocity of the gas at the smaller openings 60 is higher than the gas flow at the larger openings 50 with the result that the gas is slowed down when it contacts the catalyst 600 on the surface of membrane 550 and the residence time of gas-catalyst contact is increased and the area of gas exposure at the membrane 550 is maximized. Alternatively, the opposite arrangement can also be contemplated. This feature, together with the increased electrical conductivity of the flexible graphite electrode of the present invention enables more efficient fuel cell operation.

CLAIMS:

1. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the shape of the channels is such that channels which correspond to locations at or near where

flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

2. The electrode of claim 1 wherein the channels are designed such that the channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

3. The electrode of claim 1 wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

6. The electrode of claim 1 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

9. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the channels are designed such that the channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

10. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

11. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the channels are designed such that the channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

12. The assembly of claim 11 wherein the shape of the channels is such that channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

13. The assembly of claim 10 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

14. The assembly of claim 10 wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

16. The assembly of claim 11 wherein the density of the sheet is engineered so as

to reduce flooding in the electrochemical fuel cell.

21. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the shape of the channels is such that channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

22. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

23. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the channel openings at the first surface are larger than the channel openings at the second surface.

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L7: Entry 1 of 1 File: USPT Feb 18, 2003

US-PAT-NO: 6521369
DOCUMENT-IDENTIFIER: US 6521369 B1

TITLE: Flooding-reducing fuel cell electrode

DATE-ISSUED: February 18, 2003

INVENTOR-INFORMATION:

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US-CL-ISSUED: 429/40; 429/38, 429/39, 429/30
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PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

Search Selected Search ALL Clear

| | PAT-NO | ISSUE-DATE | PATENTEE-NAME | US-CL |
|---|---|---|---|---|
| ☐ | 3404061 | October 1968 | Shane et al. | 161/125 |
| ☐ | 4895713 | January 1990 | Greinke et al. | 423/448 |
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| ☐ | 5902762 | May 1999 | Mercuri et al. | 501/99 |
| ☐ | 6037074 | March 2000 | Mercuri et al. | 429/34 |

ART-UNIT: 1745

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ABSTRACT:

An electrode for an electrochemical fuel cell is provided. More particularly, an electrode formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second opposed surfaces of the sheet, is provided. The size, shape and/or placement of the channels, and/or the density of the sheet, is engineered so as to reduce or minimize flooding in the fuel cell.

23 Claims, 20 Drawing figures

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L7: Entry 1 of 1 File: USPT Feb 18, 2003

DOCUMENT-IDENTIFIER: US 6521369 B1
TITLE: Flooding-reducing fuel cell electrode

Abstract Text (1):
An electrode for an electrochemical fuel cell is provided. More particularly, an electrode formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second opposed surfaces of the sheet, is provided. The size, shape and/or placement of the channels, and/or the density of the sheet, is engineered so as to reduce or minimize flooding in the fuel cell.

Application Filing Date (1):
20001116

Brief Summary Text (2):
The invention relates to an engineered electrode for an electrochemical fuel cell, comprising an article formed of a flexible graphite sheet that is fluid permeable and has enhanced isotropy with respect to thermal and electrical conductivity, and which is formed so as to minimize or reduce the flooding which can at times be observed with prior flexible graphite sheets when used as an electrochemical fuel cell electrode.

Brief Summary Text (4):
An ion exchange membrane fuel cell, more specifically a proton exchange membrane (PEM) fuel cell, produces electricity through the chemical reaction of hydrogen and oxygen in the air. Within the fuel cell, electrodes denoted as anode and cathode surround a polymer electrolyte. A catalyst material stimulates hydrogen molecules to split into hydrogen atoms and then, at the membrane, the atoms each split into a proton and an electron. The electrons are utilized as electrical energy. The protons migrate through the electrolyte and combine with oxygen and electrons to form water.

Brief Summary Text (5):
A PEM fuel cell is advantageously formed of a membrane electrode assembly sandwiched between two graphite flow field plates. Conventionally, the membrane electrode assembly consists of random-oriented carbon fiber paper electrodes (anode and cathode) with a thin layer of a catalyst material, particularly platinum or a platinum group metal coated on isotropic carbon particles, such as lamp black, bonded to either side of a proton exchange membrane disposed between the electrodes. In operation, hydrogen flows through channels in one of the flow field plates to the anode, where the catalyst promotes its separation into hydrogen atoms and thereafter into protons that pass through the membrane and electrons that flow through an external load. Air flows through the channels in the other flow field plate to the cathode, where the oxygen in the air is separated into oxygen atoms, which joins with the protons through the proton exchange membrane and the electrons through the circuit, and combine to form water. Since the membrane is an insulator, the electrons travel through an external circuit in which the electricity is utilized, and join with protons at the cathode. The air stream on the cathode side

removes the water formed by combination of the hydrogen and oxygen. Combinations of such fuel cells are used in a fuel cell stack to provide the desired voltage.

Brief Summary Text (6):
One limiting factor to the use of flexible graphite sheets as the cathode for PEM fuel cells is the accumulation of water at or in the electrodes, which can interfere with operation of the fuel cell. Indeed, since the cathodic side of the fuel cell is the site of water formation during fuel cell operation, "flooding" of the cathode can occur, which physically blocks the oxygen atoms from joining with the protons, with resulting inoperability of the fuel cell.

Brief Summary Text (13):
This considerable difference in properties, i.e. anisotropy, which is directionally dependent, can be disadvantageous in some applications. For example, in gasket applications where flexible graphite sheet is used as the gasket material and in use is held tightly between metal surfaces, the diffusion of fluid, e.g. gases or liquids, occurs more readily parallel to and between the major surfaces of the flexible graphite sheet. It would, in most instances, provide for greater gasket performance, if the resistance to fluid flow parallel to the major surfaces of the graphite sheet ("a" direction) were increased, even at the expense of reduced resistance to fluid diffusion flow transverse to the major faces of the graphite sheet ("c" direction). With respect to electrical properties, the resistivity of anisotropic flexible graphite sheet is high in the direction transverse to the major surfaces ("c" direction) of the flexible graphite sheet, and substantially less in the direction parallel to the major faces of the flexible graphite sheet ("a" direction). In applications such as electrodes for fuel cells, it would be of advantage if the electrical resistance transverse to the major surfaces of the flexible graphite sheet ("c" direction) were decreased, even at the expense of an increase in electrical resistivity in the direction parallel to the major faces of the flexible graphite sheet ("a" direction).

Brief Summary Text (15):
Flexible graphite sheet can be provided with channels, which are preferably smooth-sided, and which pass between the parallel, opposed surfaces of the flexible graphite sheet and are separated by walls of compressed expanded graphite. When the flexible graphite sheet functions as an electrode in an electrochemical fuel cell, and is placed so as to abut the ion exchange membrane, so that the "tops" of the walls of the flexible graphite sheet abut the ion exchange membrane.

Brief Summary Text (16):
The potential of a flexible graphite sheet to flood when utilized as the cathode in a PEM fuel cell is addressed by the present invention.

Brief Summary Text (18):
The present invention provides an electrode for a PEM fuel cell. The electrode is formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second opposed surfaces of the sheet. The transverse fluid channels are advantageously formed by mechanically impacting an opposed surface of the graphite sheet to displace graphite within the sheet at predetermined locations to provide a channel pattern. The transverse fluid channels are separated by walls of compressed expanded graphite.

Brief Summary Text (19):
By engineering the geometry and/or location of the channels in the sheet or the characteristics of the sheet itself, water outflow from and through the sheet can be modified, and flooding, especially at the cathodic side of the fuel cell, can be reduced or even eliminated. For example, if it is determined that flooding is more likely near the outlet of the fuel cell, the channels can be designed so as to have a larger diameter than at the inlet, where gas flow to the membrane and catalyst

are the primary concern. Moreover near the outlet, the shape and/or arrangement of the channels can be engineered, such that water outflow through the electrode and gas inflow at the inlet side are each encouraged. Channel pattern density (i.e., the number of channels per square centimeter of sheet) and density of the flexible graphite sheet itself can also be advantageously employed in this regard. Likewise, combinations of the foregoing can be utilized to optimize gas inflow and water outflow.

Detailed Description Text (17):
In the practice of this invention, the flexible graphite sheet is provided with channels, which are preferably smooth-sided, and which pass between the parallel, opposed surfaces of the flexible graphite sheet and are separated by walls of compressed expanded graphite. It is the "tops" of the walls of the flexible graphite sheet that actually abut the ion exchange membrane, when the inventive flexible graphite sheet functions as an electrode in an electrochemical fuel cell.

Detailed Description Text (20):
In accordance with the present invention, the flexible graphite sheet can be designed, or engineered, such that flooding of the fuel cell, especially on the cathodic side, can be reduced or avoided. More specifically, the location along the flexible graphite sheet where flooding is most likely to occur, when the sheet is employed as a fuel cell electrode, can be identified, and the channels at or near that location can be formed having a larger cross-sectional diameter than other channels, in order to encourage water flow through those larger diameter channels. For instance, if it is determined that flooding is more likely to occur at or near the outlet of the fuel cell, then the channels at or near the outlet region can be formed so as to be larger in cross-section than the remaining channels.

Detailed Description Text (21):
Alternatively, or in addition, the shape of the channels can be engineered to help prevent flooding. As noted above, the channels can be formed such that the openings at one of the surfaces of the flexible graphite sheet are larger than the openings at the other surface. Although it may be desirable throughout the majority of the flexible graphite sheet electrode to form the channels such that the larger openings are arrayed towards the flow field plate of the fuel cell, to facilitate gas flow to the membrane, the channels can be formed so that the larger openings are arrayed towards the membrane at those locations prone to flooding (such as at or near the outlet) to facilitate water flow away from the membrane (or vice versa). Moreover, the pattern density of the channels can be designed such that the channels are more densely situated, or less densely situated but larger in cross-section, at or near the potential flooding locations, again to encourage water flow away from those areas.

Detailed Description Text (22):
Furthermore, the density of the graphite sheet itself can be advantageously employed to reduce or eliminate flooding. More specifically, forming the sheet such that its density (especially at or near those locations where flooding is most likely) is greater than about 1.3 g/cc, and more preferably greater than about 1.5 g/cc, results in an electrode less apt to flooding in an electrochemical fuel cell. Most preferred densities in this regard are between about 1.5g/cc and about 1.75 g/cc.

Detailed Description Text (23):
In an especially preferred embodiment, the channels through the flexible graphite sheet of the present invention can be engineered such that differently oriented or shaped channels are arrayed in a pattern at or near the potential flooding locations. Thus, to facilitate both gas flow away from the flow field plate and towards the membrane, and water flow away from the membrane, the channels at or near the potential flooding location(s) of the fuel cell can comprise both channels whose larger openings face the membrane and channels whose larger openings face the

flow field plate. These differently oriented channels can be simply alternated, or they can be arrayed in a pattern designed to optimize both gas flow and flooding-reduction. In this way, gas flow to the membrane can be maximized to the extent possible, even in those locations where there is a flooding danger.

Detailed Description Text (25):
As noted above, an electrochemical fuel cell includes a membrane electrode assembly that comprises an ion exchange membrane sandwiched between two electrodes, at least one of which is the above-described graphite sheet. A typical substrate for the ion (or proton) exchange membrane is a porous material, such as a glass cloth or a polymeric material such as a porous polyolefin like polyethylene or polypropylene. Preferably, for use in a commercially practical electrochemical fuel cell, the substrate for the PEM should be between about 10 and 200 microns thick, with an average pore diameter of about 0.1 to about 1.0 microns and porosity of about 50 to 98%. Perfluorinated polymers, like polytetrafluoroethylene, are sometimes preferred. The substrate can then be impregnated to control properties such as porosity. Styrene impregnants such as trifluorostyrene and substituted trifluorostyrenes have been suggested as particularly suitable for use in fuel cell proton exchange membranes. One preferred impregnant useful in the practice of the invention is available from Ion Power Inc. under the tradename Liquione-1100; an especially preferred impregnant is a perfluorinated polymer membrane sold under the tradename Nafion.RTM. by DuPont Company.

Detailed Description Text (27):
In order to facilitate and/or enable the dissociation/association reactions required for fuel cell operation, a catalyst metal is loaded on the two opposed major surfaces of the PEM. Most commonly, the catalyst is a noble metal like platinum or a platinum group metal, often loaded on graphite or carbon particles. The catalyst can be loaded directly to the surface of the PEM, or a catalyst-loaded moiety, such as activated carbon paper, can be bonded to either surface of the PEM, as would be familiar to the skilled artisan. In operation, the fluid (i.e., either hydrogen gas or oxygen gas, depending on the "side" of the membrane electrode assembly in question) contacts the catalyst. In the case of hydrogen, on the anodic side of the assembly, the catalyst catalyzes the dissociation of the hydrogen to its constituent protons and electrons; the protons then migrate through the proton exchange membrane, and the electrons are utilized as electrical energy. In the case of oxygen, on the cathodic side of the assembly, the catalyst catalyzes the association of the protons and electrons, with the oxygen, to form water.

Detailed Description Text (28):
Advantageously, the catalyst is selectively loaded on or at the proton exchange membrane in a pattern determined by the channel pattern of the electrode that faces the particular PEM side. Most preferably, the catalyst is arrayed on the PEM at locations corresponding to the walls forming channels of the graphite sheet electrode as described above, in order to maximize catalyst effectiveness. In this way, less catalyst is needed for similar electrical outputs from the fuel cell, resulting in significant savings and other advantages, such as reduced waste disposal needs.

Detailed Description Text (29):
More particularly, in operation, the reaction catalyzed by the catalyst metal, that is, the dissociation of hydrogen molecules and atoms into constituent protons and electrons, and the re-association of the protons and electrons, in combination with oxygen, into water, occurs at the point where the surfaces of the electrode meet (or abut) the ion exchange membrane. It is at this location and, effectively, only at this location, where dissociated electrons can be conducted along the electrode and dissociated protons can migrate across the membrane (and vice versa with respect to the cathodic side of the fuel cell). Thus, it is only at or near where the walls of the channels formed in the inventive graphite sheet abut the ion exchange membrane, where catalyst should be selectively loaded.

Detailed Description Text (30):
It may also be possible to reduce further the potential flooding of the flexible graphite sheet of the present invention when used as an electrode in an electrochemical fuel cell by rendering the sheet more hydrophobic (as opposed to untreated flexible graphite sheet) in order to help prevent the potential flooding resulting from water formation at or near the cathode. To do so, a water resistant additive can be used to coat or impregnate the sheet, providing added hydrophobicity while not substantially degrading the properties of the sheet useful in forming an electrochemical fuel cell cathode. Preferred water resistant additives include fluoropolymers, such as dispersions of polytetrafluoroethylene (i.e., Teflon.TM.) material.

Detailed Description Text (35):
In order to reduce the potential for flooding when flexible graphite sheet 10 is employed as an electrode in an electrochemical fuel cell, channels 20 are engineered by, for instance, engineering one or more of protrusions 75, 175, 275 and 375, such as by using larger or smaller size protrusions. Likewise, rollers 70, 72 can be engineered so as to array protrusions 75, 175, 275 and/or 375 in a specific pattern or arrangement, as discussed hereinabove. For instance, rollers 70, 72 can be engineered such that protrusions 75, 175, 275 and/or 375 of differing sizes are arrayed so that the channels at or near a potential flooding location have a larger cross-sectional diameter than other channels (as seen in FIGS. 4, 4 (A)). Alternatively, or in addition, rollers 70, 72 can be fabricated such that protrusions 75, 175, 275 and/or 375 form channels 20 so that the larger openings are arrayed towards the membrane at those locations needed to facilitate water flow away from the membrane (as seen in FIGS. 1, 1(A)). Moreover, rollers 70, 72 can be fabricated such that channels 20 are more densely situated at or near the potential flooding locations, again to encourage water flow away from those areas (as seen in FIGS. 2, 2(A)).

Detailed Description Text (36):
In an especially preferred embodiment, rollers 70, 72 are designed such that differently oriented or shaped channels 20 are arrayed in a pattern at or near the potential flooding locations. This can be accomplished by arraying protrusions 75, 175, 275 and/or 375 on each of rollers 70, 72 as illustrated in FIG. 6(A). Indeed, in this manner, sheet 110 of FIGS. 1, 1(A) can be formed, since it would be necessary to have shaped protrusions 75, 175, 275 and/or 375 impacting sheet 110 from either opposed surface 30, 40 to form channels 20 having larger opening 50 on both opposed surfaces 30, 40 on the same sheet while using only one set of rollers 70, 72. Likewise, as shown in FIGS. 3, 3(A), protrusions 75, 175, 275 and/or 375 on rollers 70, 72 can be formed so as to be complementary in shape, and aligned so as to create channels 22 having "hybrid" or a combination of the shapes which can be formed using protrusions 75, 175, 275 and/or 375 which are not complementary (as seen in FIGS. 1(A), 2(A), 4(A), 5(A)).

Detailed Description Text (37):
As noted, it is also possible to treat flexible graphite sheet 110, 112, 114, 116, 118 (and, more particularly, flexible graphite sheet 110, 112, 114, 116, 118 intended to be used as the cathode in electrochemical fuel cell 500) with a water resistant additive to further deter flooding. Moreover, flexible graphite sheet 110, 112, 114, 116, 118 can be treated with the water resistant additive either before or after resin curing, although prior to resin curing is more desirable. For instance, a resin-impregnated flexible graphite sheet 110, 112, 114, 116, 118 treated in accordance with the present invention, can be cured to at least about 250.degree. C., more advantageously at least about 350.degree. C. for at least about 30 minutes. If sheet 110, 112, 114, 116, 118 is not resin-impregnated, curing is typically at a temperature of at least about 350.degree. C. for at least about 30 minutes.

Detailed Description Text (39):
The primary criteria for the amount of water resistant additive to be applied to flexible graphite sheet 110, 112, 114, 116, 118 is the added hydrophobicity of the sheet while maintaining the desirable criteria for use of sheet 110, 112, 114, 116, 118 as a cathode in electrochemical fuel cell 500. Generally, flexible graphite sheet 110, 112, 114, 116, 118 should exhibit a weight gain in the range of about 2% to about 34% in order to achieve the desired characteristics.

Detailed Description Text (40):
The channeled gas permeable flexible graphite sheet 110, 112, 114, 116, 118 of FIGS. 1-5(A) is used as one or both electrodes in an electrochemical fuel cell 500 shown schematically in FIGS. 9, 10 and 10(A).

Detailed Description Text (41):
FIG. 9, FIG. 10 and FIG. 10(A) show, schematically, the basic elements of an electrochemical fuel cell, more complete details of which are disclosed in U.S. Pat. Nos. 4,988,583 and 5,300,370 and PCT WO 95/16287 (Jun. 15, 1995) and each of which is incorporated herein by reference.

Detailed Description Text (42):
With reference to FIG. 9, FIG. 10 and FIG. 10(A), the fuel cell indicated generally at 500, comprises electrolyte in the form of a plastic e.g. a solid polymer ion exchange membrane 550; channeled flexible graphite sheet electrodes 110, 112, 114, 116 and/or 118 in accordance with the present invention; and flow field plates 1000, 1100 which respectively abut electrodes 110, 112, 114, 116 and/or 118. Pressurized fuel is circulated through grooves 1400 of fuel flow field plate 1100 and pressurized oxidant is circulated through grooves 1200. The above described electrochemical fuel cell is combined with others in a fuel cell stack to provide the desired level of electric power as described in the above-noted U.S. Pat. No. 5,300,370.

Detailed Description Text (44):
The operation of fuel cell 500 requires that the electrodes 110, 112, 114, 116 and/or 118 be porous to the fuel and oxidant fluids, e.g. hydrogen and oxygen, to permit these components to readily pass from the grooves 1400, 1200 through electrodes 110, 112, 114, 116 and/or 118 to contact the catalyst 600 on the surfaces of the membrane 550, as shown in FIG. 10(A), and enable protons derived from hydrogen to migrate through ion exchange membrane 550. In the electrode 110, 112, 114, 116 and/or 118 of the present invention, channels 20 are positioned to adjacently cover grooves 1400, 1200 of the flow field plates so that the pressurized gas from the grooves passes through the smaller openings 60 of channels 20 and exits the larger openings 50 of channels 20 perhaps other than in an engineered portion of electrode 110, 112, 114, 116 and/or 118, in accordance with the present invention). The initial velocity of the gas at the smaller openings 60 is higher than the gas flow at the larger openings 50 with the result that the gas is slowed down when it contacts the catalyst 600 on the surface of membrane 550 and the residence time of gas-catalyst contact is increased and the area of gas exposure at the membrane 550 is maximized. Alternatively, the opposite arrangement can also be contemplated. This feature, together with the increased electrical conductivity of the flexible graphite electrode of the present invention enables more efficient fuel cell operation.

CLAIMS:

1. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the shape of the channels is such that channels which correspond to locations at or near where

flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

2. The electrode of claim 1 wherein the channels are designed such that the channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

3. The electrode of claim 1 wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

6. The electrode of claim 1 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

9. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the channels are designed such that the channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

10. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

11. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the channels are designed such that the channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

12. The assembly of claim 11 wherein the shape of the channels is such that channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

13. The assembly of claim 10 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

14. The assembly of claim 10 wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

16. The assembly of claim 11 wherein the density of the sheet is engineered so as

to reduce flooding in the electrochemical fuel cell.

21. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the shape of the channels is such that channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

22. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

23. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the channel openings at the first surface are larger than the channel openings at the second surface.

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L11: Entry 1 of 1 File: USPT Feb 18, 2003

DOCUMENT-IDENTIFIER: US 6521369 B1
TITLE: Flooding-reducing fuel cell electrode

Application Filing Date (1):
20001116

Detailed Description Text (36):
In an especially preferred embodiment, rollers 70, 72 are designed such that differently oriented or shaped channels 20 are arrayed in a pattern at or near the potential flooding locations. This can be accomplished by arraying protrusions 75, 175, 275 and/or 375 on each of rollers 70, 72 as illustrated in FIG. 6(A). Indeed, in this manner, sheet 110 of FIGS. 1, 1(A) can be formed, since it would be necessary to have shaped protrusions 75, 175, 275 and/or 375 impacting sheet 110 from either opposed surface 30, 40 to form channels 20 having larger opening 50 on both opposed surfaces 30, 40 on the same sheet while using only one set of rollers 70, 72. Likewise, as shown in FIGS. 3, 3(A), protrusions 75, 175, 275 and/or 375 on rollers 70, 72 can be formed so as to be complementary in shape, and aligned so as to create channels 22 having "hybrid" or a combination of the shapes which can be formed using protrusions 75, 175, 275 and/or 375 which are not complementary (as seen in FIGS. 1(A), 2(A), 4(A), 5(A)).

Detailed Description Text (44):
The operation of fuel cell 500 requires that the electrodes 110, 112, 114, 116 and/or 118 be porous to the fuel and oxidant fluids, e.g. hydrogen and oxygen, to permit these components to readily pass from the grooves 1400, 1200 through electrodes 110, 112, 114, 116 and/or 118 to contact the catalyst 600 on the surfaces of the membrane 550, as shown in FIG. 10(A), and enable protons derived from hydrogen to migrate through ion exchange membrane 550. In the electrode 110, 112, 114, 116 and/or 118 of the present invention, channels 20 are positioned to adjacently cover grooves 1400, 1200 of the flow field plates so that the pressurized gas from the grooves passes through the smaller openings 60 of channels 20 and exits the larger openings 50 of channels 20 perhaps other than in an engineered portion of electrode 110, 112, 114, 116 and/or 118, in accordance with the present invention). The initial velocity of the gas at the smaller openings 60 is higher than the gas flow at the larger openings 50 with the result that the gas is slowed down when it contacts the catalyst 600 on the surface of membrane 550 and the residence time of gas-catalyst contact is increased and the area of gas exposure at the membrane 550 is maximized. Alternatively, the opposite arrangement can also be contemplated. This feature, together with the increased electrical conductivity of the flexible graphite electrode of the present invention enables more efficient fuel cell operation.

CLAIMS:

1. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as

to reduce flooding in the electrochemical fuel cell, and wherein the shape of the channels is such that channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

2. The electrode of claim 1 wherein the channels are designed such that the channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

3. The electrode of claim 1 wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

6. The electrode of claim 1 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

9. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the channels are designed such that the channels which correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

10. An electrode for an electrochemical fuel cell, comprising a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, wherein the sheet is engineered so as to reduce flooding in the electrochemical fuel cell, and wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

11. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the channels are designed such that the channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell have a diameter greater than other channels in the electrode.

12. The assembly of claim 11 wherein the shape of the channels is such that channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

13. The assembly of claim 10 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

14. The assembly of claim 10 wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

16. The assembly of claim 11 wherein the density of the sheet is engineered so as to reduce flooding in the electrochemical fuel cell.

21. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the shape of the channels is such that channels that correspond to locations at or near where flooding can occur in the electrochemical fuel cell facilitate water flow away from the fuel cell membrane.

22. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the pattern of channels can be formed by selective placement of the channels, variations in channel density, variations of channel shape, or combinations thereof so as to reduce flooding in the electrochemical fuel cell.

23. A membrane electrode assembly for an electrochemical fuel cell comprising a pair of electrodes and an ion exchange membrane having opposed major surfaces positioned between the electrodes, at least one of the electrodes being formed of a sheet of a compressed mass of expanded graphite particles having a plurality of transverse fluid channels passing through the sheet between first and second parallel, opposed surfaces of the sheet in a selected pattern, the channels being separated by walls of compressed expandable graphite, the walls formed on one of the opposed surfaces abutting the ion exchange membrane, wherein the channels are designed so as to reduce flooding in the electrochemical fuel cell, and wherein the channel openings at the first surface are larger than the channel openings at the second surface.

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L3: Entry 1 of 3 File: USPT May 17, 2005

US-PAT-NO: 6893757
DOCUMENT-IDENTIFIER: US 6893757 B2

TITLE: Fuel cell apparatus and method of controlling fuel cell apparatus

DATE-ISSUED: May 17, 2005

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Kato; Kenji | Aichi | | | JP |

ASSIGNEE-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY | TYPE CODE |
|---|---|---|---|---|---|
| KabushikiKaisha Equos Research | | | | JP | 03 |

APPL-NO: 10/ 052408 [PALM]
DATE FILED: January 23, 2002

FOREIGN-APPL-PRIORITY-DATA:

| COUNTRY | APPL-NO | APPL-DATE |
|---|---|---|
| JP | 2001-018284 | January 26, 2001 |
| JP | 2001-018363 | January 26, 2001 |

INT-CL: [07] H01M00804, H01M00812

US-CL-ISSUED: 429/23; 429/25
US-CL-CURRENT: 429/23; 429/25

FIELD-OF-SEARCH: 429/22, 429/23, 429/25, 429/38, 429/39

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS



| | PAT-NO | ISSUE-DATE | PATENTEE-NAME | US-CL |
|---|---|---|---|---|
| ☐ | 3753780 | August 1973 | Fetterman | 429/23 |
| ☐ | 5334463 | August 1994 | Tajima et al. | 429/9 |
| ☐ | 5677073 | October 1997 | Kawatsu | 429/22 |
| ☐ | 6447939 | September 2002 | Iwasaki | 429/9 |

ART-UNIT: 1745

PRIMARY-EXAMINER: Ryan; Patrick Joseph

ASSISTANT-EXAMINER: Mercado; Julian

ATTY-AGENT-FIRM: Lorusso & Loud

ABSTRACT:

A fuel cell apparatus includes a fuel cell connected directly to a load. An electricity accumulation circuit including an electricity accumulator is connected in parallel to the fuel cell. The electricity accumulator supplies electric power to the load when electric power supplied by the fuel cell is less than electric power that the load requires. The electricity accumulator is charged by regenerative power generated at the load and electric power output from the fuel cell. The fuel cell outputs electric power within a predetermined range.

12 Claims, 7 Drawing figures

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L3: Entry 2 of 3 File: USPT Jun 2, 1998

US-PAT-NO: 5759712
DOCUMENT-IDENTIFIER: US 5759712 A

TITLE: Surface replica fuel cell for micro fuel cell electrical power pack

DATE-ISSUED: June 2, 1998

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Hockaday; Robert G. | Los Alamos | NM | 87544 | |

APPL-NO: 08/ 779106 [PALM]
DATE FILED: January 6, 1997

INT-CL: [06] H01 M 8/10

US-CL-ISSUED: 429/30; 429/35, 429/42, 429/26
US-CL-CURRENT: 429/30; 429/26, 429/35, 429/42

FIELD-OF-SEARCH: 429/19, 429/26, 429/30, 429/34, 429/35, 429/40, 429/42

PRIOR-ART-DISCLOSED:

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Search Selected Search ALL Clear

| | PAT-NO | ISSUE-DATE | PATENTEE-NAME | US-CL |
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| ☐ | 4243508 | January 1981 | Dankese | |
| ☐ | 4252868 | February 1981 | Bohm et al. | |
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| ☐ | 4623415 | November 1986 | Kahara et al. | |
| ☐ | 4661423 | April 1987 | Ueno et al. | |
| ☐ | 4666579 | May 1987 | Beaver et al. | |
| ☐ | 4673624 | June 1987 | Hockaday | |
| ☐ | 4769297 | September 1988 | Reiser et al. | |
| ☐ | 4793910 | December 1988 | Smotkin et al. | |
| ☐ | 4804449 | February 1989 | Sweeney | |
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| ☐ | 5240786 | August 1993 | Ong et al. |
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| ☐ | 5482568 | January 1996 | Hockaday |

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| 60-33284 | February 1985 | JP | |
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ART-UNIT: 111

PRIMARY-EXAMINER: Skapars; Anthony

ATTY-AGENT-FIRM: Wray; James Creighton Narasimhan; Meera P.

ABSTRACT:

A miniature fuel cell system uses porous plastic membranes as substrates of fuel cells. A cost effective pore-free electrode or inter electrolyte foil that is permeable only to hydrogen as an ion. The new electrode makes direct alcohol fuel cells efficient. It blocks the poisoning alcohol diffusion through the electrolyte. Compound electrodes are formed by vacuum deposition methods and slurries. That leads to printed circuit designs of small fuel cells systems integrated with rechargeable batteries and electrical power electronics to power applications that are currently powered by batteries. By directly utilizing alcohol fuels the new fuel cells have higher energy per unit mass and higher energy per unit volume. They are more convenient for the energy user, environmentally less harmful and less expensive than conventional batteries.

53 Claims, 25 Drawing figures

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L3: Entry 3 of 3 File: USPT Jan 18, 1983

US-PAT-NO: 4369235
DOCUMENT-IDENTIFIER: US 4369235 A
** See image for Certificate of Correction **

TITLE: Electrochemical cell and gas diffusion electrode for the same

DATE-ISSUED: January 18, 1983

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Bursell; Martin S. O. | Solna | | | SE |

ASSIGNEE-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY | TYPE CODE |
|---|---|---|---|---|---|
| SAB Nife AB | | | | SE | 03 |

APPL-NO: 06/ 243931 [PALM]
DATE FILED: February 25, 1981

PCT-DATA:

| APPL-NO | DATE-FILED | PUB-NO | PUB-DATE | 371-DATE | 102(E)-DATE |
|---|---|---|---|---|---|
| PCT/SE80/00176 | June 25, 1980 | WO81/00032 | Jan 8, 1981 | Feb 25, 1981 | Feb 25, 1981 |

INT-CL: [03] H01M 12/00

US-CL-ISSUED: 429/27; 429/101
US-CL-CURRENT: 429/27; 429/101

FIELD-OF-SEARCH: 429/12, 429/13, 429/27, 429/28, 429/29, 429/101,, 429/44, 429/40, 429/41, 429/42, 429/45, 429/57, 429/58, 429/59, 429/60

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

Search Selected Search ALL Clear

| | PAT-NO | ISSUE-DATE | PATENTEE-NAME | US-CL |
|---|---|---|---|---|
| ☐ | 2213429 | September 1940 | Heise et al. | 429/27 |
| ☐ | 2907809 | October 1959 | Southworth et al. | 429/27 |
| ☐ | 3096215 | August 1963 | Voss et al. | 429/59 |

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| ☐ | 3102059 | August 1963 | Harmer | 429/57 |
| ☐ | 3600230 | August 1971 | Stachurski et al. | 429/27 |
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FOREIGN PATENT DOCUMENTS

| FOREIGN-PAT-NO | PUBN-DATE | COUNTRY | US-CL |
|---|---|---|---|
| 48-7318741 | August 1973 | JP | 429/101 |

ART-UNIT: 112

PRIMARY-EXAMINER: Walton; Donald L.

ATTY-AGENT-FIRM: Burns, Doane, Swecker & Mathis

ABSTRACT:

An electrochemical cell is described, as well as a gas diffusion electrode for the same. The electrode is of the type which is on an exterior surface provided with a catalyst for converting gas to electricity and on an interior surface with a hydrophobic material. The hydrophobic material comprises a cohesive porous plastics layer, which defines a closed gas space within the electrode, and which the electrolyte cannot enter, although the electrode is immersed therein. On the other hand, gas can be sucked into and can pass out from the space. When the electrode is partially immersed in the electrolyte, gas is automatically sucked from the atmosphere above the electrolyte level in the cell and into the gas space, due to the subpressure in the space occurring during operation. By reason of the capacity of the electrode it has been possible to make the cell according to the invention entirely closed off in relation to the surrounding atmosphere, which means a very simplified construction without gas conduits to the cell. The cell is especially utilizable as a metal/oxygen battery, fuel cell and metal oxide/hydrogen battery.

18 Claims, 3 Drawing figures

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